

Incidence of abdominal obesity and its risk factors among Tehranian adults

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Abstract

Objective: Abdominal obesity (AO) is a relative risk factor for cardiovascular events. We aimed to determine the 6-year incidence of AO and its risk factors among Tehranian adults.

Design/Setting/Subjects: In this population-based cohort study, non-abdominally obese participants, aged ≥ 20 years, were followed for incidence of AO. Cumulative incidence and incidence rate of AO were calculated for each sex. Cox proportional hazard regression was used to determine the association of potential risk factors including age, BMI, dysmetabolic state, smoking, marital status, educational level and physical activity (PA).

Results: A total of 5044 participants (1912 men) were followed for a median of 6 years. Mean age was 37.7 (SD 13.5) years at baseline, with mean BMI of 24.3 (SD 3.1) kg/m² (men, 23.0 (SD 2.4) kg/m²; women, 25.0 (SD 3.2) kg/m²). During follow-up, 3093 (1373 men) developed AO with total cumulative incidence of 76.02, 83.59 and 70.90%, for the whole population, men and women, respectively. Corresponding incidence rates were 96.0, 138.7 and 77.1 per 1000 person-years. The highest incidence rate was observed during their 30s and 50s, in men and women, respectively. Subjects with dysmetabolic state in both sexes, married women, men with lower PA and higher educational levels at baseline were at higher risk of AO.

Conclusions: The incidence of AO is high among Tehranian adults, especially in young men. The risk factors for developing AO should be highlighted to halt this growing trend of AO.

Keywords
Abdominal obesity
Obesity
Incidence
Adults
Risk factors

Obesity has become a global health burden owing to its complications such as hypertension, type 2 diabetes, dyslipidaemia, coronary artery disease, stroke and cancer^(1,2). Overweight and obesity affected over 600 million adults in 2014 worldwide, a rate expected to be about 1.2 billion in 2030⁽³⁾. Commonly BMI is used to determine body fat, but it is not a strong predictor of total body fat and subsequently the risk of CVD. In contrast, waist circumference (WC) as a measure of abdominal obesity (AO) identifies the risk of cardiometabolic disease more precisely than BMI⁽⁴⁾. A population-based study in the USA reported that 7.6% of adults aged ≥ 20 years had AO and 33.7% had abnormal waist-to-hip ratio in 2012⁽⁵⁾. The importance of intervention and control of AO as a universal concern is clarified by a study in the National Health and Nutrition Examination Survey (NHANES) framework,

which revealed a significant increase in overall AO prevalence from 46.4% in 1999–2000 to 54.2% in 2011–2012 within a population consisting of men, women, non-Hispanic whites, non-Hispanic blacks and Mexican Americans⁽⁶⁾. In the Iranian adult population, AO is more prevalent in women than in men and in older ages in both sexes⁽⁷⁾. Based on data from the Tehran Lipid and Glucose Study (TLGS) through phases 1 to 4 (1999 to 2011), AO prevalence increased from 52 to 78% in men and from 44 to 66% in women⁽⁸⁾. Incidence studies are needed to identify the high-risk individuals for AO. Since AO is a highly relative risk factor for cardiovascular events^(9,10), focus on a cohort study would help clarify of the incidence and risks of AO. We aimed to explore the incidence of AO and its risk factors in an adult Tehranian population in the TLGS over a median 6 years of follow-up.

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Methods

Study population

Using the data of participants of the TLGS, a dynamic prospective population-based study, the present study was conducted on a representative sample of the Tehranian population with the aim of determining the prevalence and risk factors of non-communicable diseases. Details of study protocol are available elsewhere^(11,12). To summarize, the TLGS has two major components: (i) a cross-sectional prevalence study of non-communicable disease (1999–2001) and associated risk factors; and (ii) prospective follow-up studies at approximately 3-year intervals. About 15 005 residents participated in the first examination cycle (1999–2001) and another 3555 residents were first examined at the second examination cycle (2002–2005). Of these 18 560, a total of 12 808 participants aged ≥ 20 years at baseline were selected for the current study. Participants with AO (n 5524), BMI below 18.5 kg/m² (n 322), pregnancy (n 98), corticosteroid consumption (n 245) at baseline and those without any follow-up data (n 1575) were excluded, leaving 5044 participants to be followed up to 2014.

All participants provided written, informed consent. The protocol of the present study, conducted in accordance with principles of the Declaration of Helsinki, was approved by the ethics committee of the Research Institute of Endocrine Sciences of Shahid Beheshti University of Medical Sciences.

Clinical and laboratory measurements

Using a pre-tested questionnaire, a trained interviewer collected information which included baseline demographic information, family history of diabetes, past medical history of CVD, drug use and smoking behaviour. Weight was measured with participants minimally clothed without shoes, using digital scales (Seca 707; Seca Corporation, Hanover, MD, USA; range 0.1–150 kg), and recorded to the nearest 100 g. Height was measured in a standing position without shoes, using a tape meter that was fixed to a wall, while shoulders were in a normal alignment. WC was measured at the umbilical level. Two measurements of systolic blood pressure and diastolic blood pressure were taken using a standardized mercury sphygmomanometer on the right arm, after resting for 15 min in a sitting position; the mean of the two measurements was considered as the participant's blood pressure. Fasting plasma glucose, HDL-cholesterol and TAG levels were measured by previously reported methods⁽¹²⁾. BMI was calculated as weight (in kilograms) divided by the square of height (in metres).

Definition of terms

Abdominal obesity was defined as WC ≥ 91 cm for women and WC ≥ 89 cm for men⁽¹³⁾. The definition of

dysmetabolic state was according to the criteria for metabolic syndrome of the Joint Interim Statement⁽¹⁴⁾, with exclusion of AO, as the presence of any three out of the following four components: (i) fasting plasma glucose ≥ 5.6 mmol/l (100 mg/dl) or 2 h plasma glucose ≥ 7.8 mmol/l (140 mg/dl) or drug treatment; (ii) fasting TAG ≥ 1.7 mmol/l (150 mg/dl) or drug treatment; (iii) fasting HDL-cholesterol of 1.29 mmol/l (50 mg/dl) in women and 1.03 mmol/l (40 mg/dl) in men or drug treatment; and (iv) raised blood pressure defined as systolic blood pressure ≥ 130 mmHg, diastolic blood pressure ≥ 85 mmHg or antihypertensive drug treatment. Data on physical activity (PA) were assessed using the Lipid Research Clinics questionnaire in the first phase of the TLGS. Due to the lack of precision of the Lipid Research Clinics questionnaire⁽¹⁵⁾, the Modifiable Activity Questionnaire, which measures all three types of activity including leisure-time, job and household activities⁽¹⁶⁾, was used in the rest of the follow-up examinations. Since the duration of PA was not accounted for in the Lipid Research Clinics questionnaire, participants who were enrolled in the study from the first phase of the TLGS were considered 'low PA' if participating in low and moderate PA and considered 'high PA' if participating in vigorous PA for a minimum of 3 d/week. Individuals who entered the study at the second follow-up examination of the TLGS were defined as 'high PA' if they achieved a minimum of at least 600 MET-min/week and as 'low PA' if they had less than 600 MET-min/week (where MET is metabolic equivalent of task)⁽¹⁷⁾. Education was classified into two groups: below diploma (<12 years education); and diploma or higher (≥ 12 years education). Marital status was categorized as single (including widowed) and married. A current smoker was defined as a person who smokes cigarettes daily or occasionally. Ex-smokers were considered non-smokers.

Statistical analysis

All analyses were conducted separately for men and women. Categorical variables of the baseline characteristics are expressed as n and %. Comparison of baseline characteristics between men *v.* women was done using a χ^2 test. In the present study, the exact time of AO incidence was calculated by the interval-censored data method. Interval censoring takes account of the event happening between two time periods. Considering alternative interval-censoring approaches, results were investigated using mid-point censoring⁽¹⁸⁾. Mid-point censoring was set to the mid-point between the last negative and the most recent positive event time. End points were considered as the time of incident AO and censoring was defined as lost to follow-up or end of the follow-up. Cumulative incidence of AO with 95% CI was calculated for each sex as the number of new cases of AO over the total number of individuals in that group minus half of the

Table 1 Baseline characteristics of study participants. Tehran Lipid and Glucose Study, 1999–2014

Characteristic	Total (n 5044)		Men (n 1912)		Women (n 3132)		P value
	n	%	n	%	n	%	
Age group (years)							
20–29	1642	32.6	579	30.3	1063	33.9	<0.0001
30–39	1521	30.2	521	27.2	1000	31.9	
40–49	891	17.7	322	16.8	569	18.2	
50–59	528	10.5	228	11.9	300	9.6	
60–69	350	6.9	180	9.4	170	48.6	
≥70	112	2.2	82	4.3	30	1.0	
Educational level							
< 12 years	4014	83.6	1491	80.7	2523	85.3	<0.0001
≥ 12 years	790	16.4	356	19.3	434	14.7	
Marital status							
Non-married	1236	24.5	553	28.9	683	21.8	<0.0001
Married	3808	75.5	1359	71.1	2449	78.2	
BMI group (kg/m ²)							
18.5–21.5	973	20.5	514	27.3	459	16.1	<0.0001
21.5–25.0	2073	43.7	993	52.7	1080	37.8	
25.0–27.5	1175	24.8	349	18.5	826	28.9	
27.5–30.0	518	10.9	29	1.5	489	17.1	
Dysmetabolic state							
No	4167	86.9	1580	87.3	2587	86.6	0.515
Yes	629	13.1	230	12.7	399	13.4	
Physical activity*							
Low	3337	70.0	1316	71.8	2021	68.8	0.026
High	1433	30.0	516	28.2	917	31.2	
Smoking status							
Non-smoker	4349	87.3	1344	71.1	3005	97.2	<0.0001
Current smoker	631	12.7	545	28.9	86	2.8	

*Physical activity measured by the Lipid Research Clinics questionnaire and the Modifiable Activity Questionnaire.

censored population. The person-year method was used to obtain AO incidence rates, which are reported as the number of cases per 1000 person-years. Cox proportional hazard modelling was used to estimate unadjusted and age-adjusted hazard ratios (HR) along with 95% CI for baseline groups of BMI, PA, dysmetabolic state, educational level, smoking status and marital status. The proportionality assumption was verified by assessing the correlation between the Schoenfeld residuals and person-days along with observing log minus log plots (considering different groups as strata variables). All analyses were performed using the statistical software packages IBM SPSS for Windows version 20 and Stata version 12 SE, with a two-tailed *P* values of 0.05 being considered significant.

Results

In the present study, 5044 participants (37% male), with mean age of 37.7 (SD 13.5) years, mean BMI of 24.3 (SD 3.1) kg/m² (23.0 (SD 2.4) and 25.0 (SD 3.2) kg/m² for men and women, respectively) and mean WC of 79.8 (SD 6.8) cm (80.2 (SD 5.8) and 79.5 (SD 7.4) cm for men and women, respectively) at baseline, were followed for a median of 6 years (25th–75th percentile: 2–10 years). Baseline characteristics of the participants are shown in Table 1. In addition, regarding individual components of dysmetabolic state, 1602 (32.3%)

had high TAG, 3334 (67.1%) had low HDL-cholesterol, 1043 (20.7%) had high blood pressure and 674 (13.4%) had high fasting plasma glucose.

Men had significantly less PA and a higher frequency of smoking than women at baseline. There was no significant difference between the sexes in prevalence of dysmetabolic state.

During follow-up, 3093 subjects (1720 women) developed AO that led to a cumulative incidence of 76.02 (95% CI 74.70, 77.32)%. Total cumulative incidence of AO was 70.90 (95% CI 69.08, 72.69)% for women and 83.59 (95% CI 81.76, 85.34)% for men.

Incidence rate in the whole population was 96.0 (95% CI 92.7, 99.5) per 1000 person-years. Corresponding incidence rates among men and women were 138.7 (95% CI 131.5, 146.3) and 77.1 (95% CI 73.5, 80.9) per 1000 person-years. The highest incidence rate in women was 146.3 (128.1, 167.0) per 1000 person-years in the 50–59 years age group and in men was 152.6 (138.2, 168.5) per 1000 person-years in the 30–39 years age group. Median survival for men was 4 (SD 2.8) years *v.* 7 (SD 3.1) years for women.

The association of different risk factors with developing incident AO from clinical and demographic predictors is presented in Table 2 (men) and Table 3 (women).

Dysmetabolic state and BMI were significantly associated with increasing incident AO in both sexes. Higher educational level in men significantly increased the risk of

Table 2 Cumulative incidence, hazard ratios and incidence rate of potential risk factors of abdominal obesity in men. Tehran Lipid and Glucose Study, 1999–2014

Characteristic	Cumulative incidence	95% CI	HR	95% CI	Age-adjusted HR	95% CI	IR (per 1000 person-years)	95% CI
Age group (years)								
20–29	0.86	0.83, 0.89	1.00	Ref.	–	–	146.5	133.5, 160.8
30–39	0.86	0.83, 0.89	1.05	0.92, 1.21	–	–	152.6	138.2, 168.5
40–49	0.80	0.75, 0.85	0.85	0.72, 1.00	–	–	121.4	106.3, 138.8
50–59	0.80	0.74, 0.85	0.87	0.72, 1.05	–	–	125.0	106.6, 146.5
60–69	0.77	0.70, 0.83	0.88	0.72, 1.09	–	–	121.2	100.6, 146.1
≥ 70	0.73	0.62, 0.83	1.00	0.78, 1.42	–	–	149.6	112.4, 199.2
Educational level								
< 12 years	0.83	0.81, 0.85	1.00	Ref.	1.00	Ref.	134.7	126.8, 143.1
≥ 12 years	0.87	0.83, 0.91	1.20	1.05, 1.37	1.2	1.05, 1.37	163.2	145.0, 183.6
Marital status								
Non-married	0.86	0.82, 0.89	1.00	Ref.	1.00	Ref.	143.6	130.4, 158.1
Married	0.82	0.80, 0.84	0.97	0.87, 1.09	0.99	0.99, 1.00	136.6	128.1, 145.6
BMI group (kg/m²)								
18.5–21.5	0.62	0.57, 0.67	1.00	Ref.	1.00	Ref.	60.0	52.8, 68.3
21.5–25.0	0.87	0.85, 0.89	2.70	2.30, 3.10	2.80	2.40, 3.20	164.4	153.2, 176.5
25.0–27.5	0.96	0.94, 0.98	5.10	4.30, 6.00	5.20	4.40, 6.20	301.8	270.5, 336.8
27.5–30.0	0.96	0.84, 0.99	4.20	2.80, 6.30	4.20	2.80, 6.30	264.7	181.5, 385.9
Dysmetabolic state								
No	0.83	0.81, 0.85	1.00	Ref.	1.00	Ref.	133.7	126.1, 141.8
Yes	0.88	0.83, 0.92	1.34	1.15, 1.57	1.38	1.17, 1.61	182.5	157.7, 211.2
Physical activity*								
Low	0.84	0.82, 0.86	1.00	Ref.	1.00	Ref.	141.9	133.2, 151.1
High	0.80	0.77, 0.84	0.92	0.82, 1.00	0.92	0.81, 1.00	131.1	118.0, 145.7
Smoking status								
Non-smoker	0.84	0.82, 0.86	1.00	Ref.	1.00	Ref.	142.5	133.8, 151.7
Current smoker	0.81	0.77, 0.84	0.90	0.80, 1.01	0.90	0.80, 1.01	128.4	115.9, 142.2

Cumulative incidence = number of incident obesity cases divided by the total number of individuals; HR, hazard ratio; IR, incidence rate = number of incident obesity cases divided by the person-years of follow-up; Ref., reference category.

*Physical activity measured by the Lipid Research Clinics questionnaire and the Modifiable Activity Questionnaire.

AO, in contrast to women (HR = 1.20; 95% CI 1.05, 1.37 in men and HR = 0.67; 95% CI 0.57, 0.78 in women). Ageing was significantly associated with AO in women, with the highest HR in the 50–59 years age group (HR = 3.19; 95% CI 2.70, 3.75).

Married status was a significant risk factor of developing AO in women, whereas marital status in men was not significantly associated with AO. Smoking status and PA were not among predictors of AO, in men or women.

Discussion

After a median of 6 years of follow-up, the present study indicated high incidence of AO in an urban adult Tehranian population, which was higher among men than women (83.5 *v.* 70.9%). Important risk factors of developing AO at baseline were dysmetabolic state and BMI in both sexes, high educational level and less PA in men, and married status in women. Moreover, men mostly developed AO earlier than women (30–39 *v.* 50–59 years).

There are limited studies investigating the incidence of AO worldwide, which differ in terms of the mean age of subjects, socio-economic status, WC cut-offs and length

of follow-up. Haftenberger *et al.* reported a high rate of AO within 10 years among adults, by including the data of 15 444 men and 17 207 women from seven prospective cohort studies in Germany. The rate of progression to AO in participants with low baseline WC (<94 cm in men; <80 cm in women) was reported near to 20%. Moreover, this rate was higher (50%) among participants with intermediate WC (94–102 cm in men; 80–88 cm in women) at baseline⁽¹⁹⁾. Another study from Europe reported age-adjusted incidence of AO in an urban Portuguese population to be 59.7 and 23.8 per 1000 person-years for women and men, respectively⁽²⁰⁾, which was lower than that of our population. In Iran, as a middle-income country, we found higher incidence of AO as compared with both above-mentioned results from high-income countries. Rising trends of non-communicable diseases including obesity and AO have been reported in low- and middle-income countries during recent years⁽²¹⁾. In fact, industrialization and alterations in occupations and transportation systems cause changes in nutrition pattern⁽²²⁾. According to studies conducted in China, AO has increased dramatically from 12% in 1993 to 21% in 2009 in people with normal BMI, specifically in men. Interestingly, this rising trend was observed in both sexes, rural and urban areas, all ages and education groups⁽²³⁾. In Iran as a

Table 3 Cumulative incidence, hazard ratios and incidence rate of potential risk factors of abdominal obesity in women. Tehran Lipid and Glucose Study, 1999–2014

Characteristic	Cumulative incidence	95 % CI	HR	95 % CI	Age-adjusted HR	95 % CI	IR (per 1000 person-years)	95 % CI
Age group (years)								
20–29	0.56	0.52, 0.59	1.00	Ref.	–	–	46.8	42.5, 51.5
30–39	0.72	0.69, 0.75	1.66	1.46, 1.88	–	–	77.9	71.8, 84.6
40–49	0.81	0.77, 0.84	2.45	2.13, 2.81	–	–	112.6	101.9, 124.4
50–59	0.80	0.74, 0.85	3.19	2.70, 3.75	–	–	146.3	128.1, 167.0
60–69	0.75	0.68, 0.82	2.38	1.92, 2.96	–	–	109.8	90.5, 133.2
≥ 70	0.69	0.50, 0.86	2.62	1.59, 4.33	–	–	112.7	67.9, 187.0
Educational level								
< 12 years	0.72	0.70, 0.74	1.00	Ref.	1.00	Ref.	79.7	75.7, 84.0
≥ 12 years	0.60	0.55, 0.66	0.67	0.57, 0.78	0.76	0.65, 0.88	54.1	46.9, 62.4
Marital status								
Non-married	0.56	0.52, 0.61	1.00	Ref.	1.00	Ref.	50.6	44.9, 57.1
Married	0.74	0.72, 0.76	1.68	1.48, 1.92	1.51	1.32, 1.72	85.3	81.0, 89.8
BMI group (kg/m²)								
18.5–21.5	0.28	0.23, 0.34	1.00	Ref.	1.00	Ref.	17.4	13.9, 21.7
21.5–25.0	0.60	0.56, 0.63	3.02	2.37, 3.85	2.63	2.06, 3.35	51.4	46.9, 56.3
25.0–27.5	0.80	0.77, 0.83	6.38	5.02, 8.10	5.45	4.28, 6.93	104.8	96.4, 113.9
27.5–30.0	0.91	0.88, 0.93	11.27	8.80, 14.30	9.50	7.42, 12.10	177.6	161.1, 195.7
Dysmetabolic state								
No	0.69	0.67, 0.71	1.00	Ref.	1.00	Ref.	72.3	68.6, 76.2
Yes	0.81	0.76, 0.85	1.71	1.50, 1.95	1.13	1.00, 1.30	123.3	109.4, 138.9
Physical activity*								
Low	0.72	0.70, 0.74	1.00	Ref.	1.00	Ref.	77.8	73.4, 82.5
High	0.70	0.66, 0.73	0.98	0.88, 1.09	0.98	0.88, 1.09	76.8	70.3, 84.0
Smoking status								
Non-smoker	0.70	0.69, 0.72	1.00	Ref.	1.00	Ref.	77.0	73.4, 80.8
Current smoker	0.74	0.63, 0.84	1.11	0.84, 1.47	0.99	0.75, 1.32	86.2	65.5, 113.5

Cumulative incidence = number of incident obesity cases divided by the total number of individuals; HR, hazard ratio; IR, incidence rate = number of incident obesity cases divided by the person-years of follow-up; Ref., reference category.

*Physical activity measured by the Lipid Research Clinics questionnaire and the Modifiable Activity Questionnaire.

developing country, low PA, sedentary lifestyle, changes in diets and higher energy intake are suggested to play key roles in this alarming rise in incidence of AO^(24,25).

The causes of developing AO are multifactorial, including PA, education, marital status, socio-economic status and smoking⁽²⁶⁾. As a key factor to burn off excess energy, PA is consistently associated with lower risk of AO^(27,28). In our study, males with a high level of PA were at lower risk of AO. As our females mostly became abdominally obese during 50–59 years of age, the absence of an association between baseline PA and developing AO could be related to the hormonal changes during menopause, as fat distribution in women results in AO during this period⁽²⁹⁾. Moreover, we found dysmetabolic state to be a risk factor for developing AO. Previous studies revealed that metabolic syndrome components in healthy people can independently predict the incidence of metabolic syndrome itself. Therefore, it could be anticipated that people with an unhealthy metabolic status would be at risk of developing AO as a key component of the metabolic syndrome^(30,31). Moreover, it has been shown that individuals with unhealthy metabolic status without AO are at increased risk of cardiovascular events, compared with non-abdominally obese and healthy metabolic individuals^(32,33).

Moreover, high educational level has been proposed as a protective factor for developing AO mostly in women⁽³⁴⁾. Likewise, in our study, women with high education levels were at lower risk of AO. Additionally, differences in the incidence of AO between age groups and sexes were depicted in our results by the large proportion of men aged 30–39 years who developed AO; this could be attributed to the high energy density and protein intakes of young men⁽³⁵⁾. In contrast, young females did not develop AO, which could be a result of the importance of healthy diets to young women because of their higher educational level and health programmes focusing on women's health in recent years^(36,37).

Studies have reported diverse kinds of associations of AO with marital status. In a Greek investigation of both men and women, those with married status were at higher risk of AO⁽³⁸⁾. However, an Iranian study reported this association only for married women, not men⁽⁸⁾. Our findings are in agreement with these studies about women, but not men. Interestingly, another report highlights the importance of transition into or out of marriage in cohort studies and the risk of AO⁽³⁹⁾. Therefore, since marital status was not tracked in our study, we have to be cautious about interpreting our findings in this regard.

Although both smoking and amount of smoking are reported to be positively associated with developing AO^(40–42), we found no such an association in our study. Several possible reasons for this unexplained finding can be suggested, including behavioural changes in individuals which led to quitting smoking⁽¹²⁾ and lack of information regarding the dose–response relationship between smoking and development of AO.

Finally, a number of potential shortcomings in our study have to be considered. First, the TLGS is a cohort study conducted on urban Tehranians. Therefore, our results could not be generalized to the whole Iranian population, especially rural areas. Second, we used umbilicus level instead of midpoint for measurement of WC. It has been reported that WC measurement at midpoint is slightly lower than WC measurement at umbilicus and may influence the prevalence of AO. Therefore, the high incidence of AO in our report can, in part, be explained by this measurement^(43,44). Third, some important risk factors for incidence of AO such as dietary habits and socio-economic status were not taken into account. In addition, we measured all possible risk factors at a single time point at the beginning of the study; however, similar to us, most epidemiological studies in this field have provided single-point measurements for possible risk factors. The present study has its own strengths as well; to the best of our knowledge, it is one of the few population-based studies with an intermediate length of follow-up that evaluates the sex-stratified incidence of AO and its risk factors. We also used measured data for anthropometric parameters, rather than self-reported data.

Future studies on the current topic are required to investigate the effect over longer follow-ups, tracking changes of risk factors by repeated measurements and including the impact of nutrition, socio-economic and menopausal status on the incidence of AO. The evidence from the present study implies that in a large metropolitan city of a developing country, over a median follow-up of 6 years, the incidence of AO is high especially among young men, which requires that current health priorities and strategies should target this age group to provide effective prevention. Moreover, we recommend more focus on screening the general population for dysmetabolic state as an outstanding risk factor for developing AO in both sexes.

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